wind movement is considerably less, though the southeasterly wind in September is yet strong. An examination of the records indicates that this unusual rainfall is due to cyclonic activity. For illustration: During the months of September in the last 10 years, 1911 to 1921, a total of 38.23 inches has been recorded at Corpus Christi. Of that amount 21.11 inches fell in five 24-hour periods, and during all of those periods the prevailing wind was from some point from east to north, indicating a deflection of the prevailing wind due to some tropical or other disturbance.

and evaporated. Hence wind movement is the important factor in the production of rainfall over this region. Therefore a further study into the causes of the monsoon in summer over the Texas coast, a determination of inequalities of temperature over extended land and water surfaces, and a study perhaps of upper air circulation and the relation between the strength of this current and the general pressure distribution may all yield important results in connection with forecasts of precipitation, and may make possible seasonal rain forecasts for the region bordering the Texas coast.

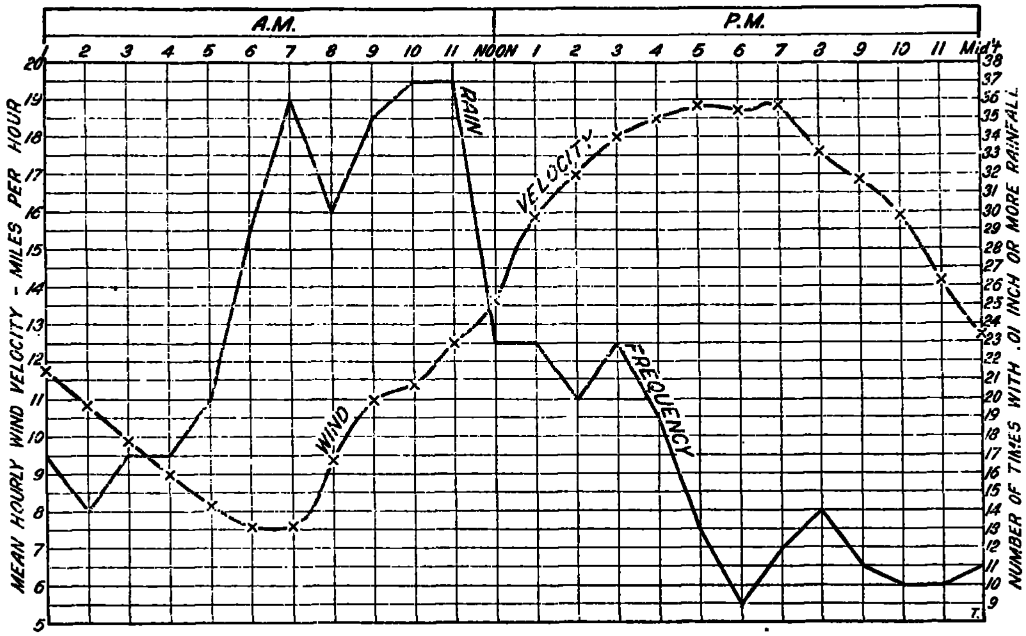

FIG. 1.—Relation between rain frequency and wind velocity on the South Texas Coast.

The southeasterly wind is so strong during the daytime that it obscures in the averages any temporary lull that aids convection and any delay of the increase of wind in in the morning, hence no very clear relationship can be established between daily wind movements and frequency of rainy days. Yet this relationship over extended periods is consistent and noticeable. For example, in the very dry year, 1917, at Corpus Christi, with only 5.38 inches of rainfall, the total wind movement was 118,106 miles, whereas, in the wet year, 1919, with 34.31 inches, the total wind movement was 101,813. During the dry year, 1917, there was only 0.26 inch of rainfall in June with 12,685 miles of wind, while in the wet year, 1919, there were 6.24 inches of rain in July with a wind movement of 7,775. These departures from normal rainfall were not local. The drougth of 1917 was marked over the entire State and all southern Texas received an excess of rainfall in 1919. It is therefore evident that changes in the velocity of wind in the summer monsoon affect not only the local rainfall but that of the coast section and much of the interior.

CONCLUSION.

Much of the coast section and interior adjoining the coast section of Texas is dependent upon convection for precipitation from its prevailing moisture bearing winds. When the southeasterly wind is strong, local inequalities of temperature at the surface are prevented and cloud masses, after formation, are mixed with surrounding air

THE MASS-GROUPING OF RAINDROPS.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., Sept. 19, 1921.]

A number of years ago, Defant[1] made an extensive study of the masses of raindrops. Measurements of more than 10,000 drops, representing several different storms, showed that in each case the drops grouped themselves chiefly about the mass ratios 1 : 2 : 4 : 8 : . . .

Recently Prof. T. Okada, of Japan, told me that he had repeated Defant's observations and that he had found the same results. Apparently, therefore, the observational evidence is quite sufficient to justify the tentative assumption that the phenomenon reported is practically universal, and to call for an effort to explain it.

It may be assumed (the justifying evidence need not be here repeated) that rain seldom occurs except in rising air. If this be true it follows that only those drops can fall from the cloud that are heavy enough to overcome the lift of the upward current, and that close to the under surface of the cloud the greatest number of drops actually descending are those that have substantially the minimum falling size. Let the mass of this minimum drop (minimum under the existing conditions) be m.

Now, drops of the same size, and under like conditions, fall with the same velocity, and, if once close together, continue close together for some time; whereas drops of

[1] *Sitzungsberichte der K. Akad. der Wiss.*, Wien, p. 114: 585, 1905.

unequal size quickly separate. Clearly, then, drops of equal size are more likely to be brought together by fortuitous disturbances—gusts, turbulences, and the like—than are drops of unequal size.

Furthermore, as explained by Schmidt,[2] two drops falling side by side are slowly pushed together, just as passing boats are driven toward each other, with a force that depends in a known way (the full solution involves considerable mathematics) upon the velocity of fall, the size of the drops, and their distance apart.

Hence, because drops of the same size fall with the same speed they are more likely to be brought together through fortuitous disturbances, and through dynamical action of the atmospheric current past them (resulting from their fall through the air), than are drops of unequal size and consequent different velocity.

Finally, then, given drops of the initial mass m at the base of the cloud, the rain drops at the surface of the earth will tend to group themselves in the mass ratios

$$m : 2m : 4m : 8m : \ . \ . \ . \ .$$

just as observation has shown them actually to be grouped.

551.54 : 551.578.1

FALLING RAIN AND ATMOSPHERIC PRESSURE.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., Sept. 1, 1921.]

It is well known that a spray of water falling down a vertical pipe increases the air pressure at the bottom of that pipe. In fact for more than 2,000 years this simple device in some form has held its own in the production of blasts for smelting and other purposes.

For simplicity assume the drops to be evenly distributed throughout the tube and falling with a uniform velocity, a condition that well may be closely approached. Under such conditions the viscous drag of each drop on the air within the tube is equal exactly to its own weight. Hence when the blast is shut off, the pressure per unit area at the bottom of the tube is $(w-a)/s$, in which w is the weight of all the water in the column of spray, a the weight of the air displaced by this spray, and s the cross section of the tube. Clearly, then, with plenty of water and a high pipe almost any increase in pressure may be obtained.

Now, at the time of a heavy shower the column is half a mile high or more, and the water in it at any given instant sufficient, perhaps, to produce a rainfall an eighth of an inch deep. But the process of falling of these drops does *not* increase the barometric pressure, as one might infer from the action of the spray trompe that it would.

Before the rain begins the barometer measures the gravity pressure of all the atmosphere, including the water vapor, above it. Let now some of the vapor be condensed into droplets. So long as these are falling with uniform velocity their pull down on the atmosphere is exactly equal to their weight, and hence this pull can not increase the pressure of the air on the surface of the earth below them. When two or more droplets unite the weight of the resulting drop is the sum of the weights of the several separate parts that so united, while its drag on the air at first is much less than the sum of the initial drags. Hence, by the amount of this decrease the pressure on the surface of the earth is also decreased. But the velocity of fall of the enlarged drop is immediately accelerated, and the acceleration continues until the drag becomes again equal to the weight and hence the surface pressure brought back to its previous value. As the drops reach the earth the total air pressure is correspondingly reduced, and slight readjustments occur in the distribution of the atmosphere which it would be tedious to attempt to follow in detail.

In the process, therefore, of condensation and rainfall, while air flows into the partial vacuum caused by the condensing of the water vapor, thus causing slight pressure changes, and while the total pressure of the atmosphere is reduced by the weight of the water reaching the surface, and while immeasurably minute decreases in pressure temporarily follow the union of smaller drops into larger, the viscous drag of the rain on the air does not raise the surface pressure above its original value, as occurs at the bottom of a pipe in which spray is falling. In the case of rain there is either weight (while vapor) or equivalent drag (of the drops) on the atmosphere, so that transfer from the one to the other can not affect the surface pressure. In the case of the spray, on the other hand, the weight is not on the air, but on the feed tube, while the drag of the falling drops is on the air within the vertical pipe. In this case the transfer is not from weight on the air to drag on the air (an equal gain and loss) but from weight on an independent support to drag on the air, a net gain in respect to the atmospheric pressure.

[2] *Met. Zeit.*, 25, p. 496, 1908.

DO THE GREAT LAKES DIMINISH RAINFALL IN THE CROP-GROWING SEASON?

551.578.1 (285 : 71 : 73)

By CYRUS H. ESHLEMAN, Meteorologist.

[Weather Bureau, Ludington, Mich., Sept. 19, 1921.]

SYNOPSIS.

During the severe drought in the early summer months of 1921, at Ludington, Mich., showers frequently seemed to avoid the shore of Lake Michigan. This led the writer to investigate the question whether or not the Lake actually causes a diminution in the normal amounts. The records show an area of maximum fall in the interior of extreme southern Michigan, in May, June, and July. In August and September the area is absent. Less rainfall occurs along the eastern than the western shore of Lake Michigan, and there is a maximum area in the interior of Wisconsin. Apparently the Lakes do cause some diminution. The probable cause is the Lake breezes during the middle of the day and the afternoon, strongest in May, June, and July, which promote circulation and have a lateral movement that prevents the ascending currents needed for local thunderstorms. In general, however, the monthly amounts are sufficient for agricultural interests.

Severe drought conditions prevailed during the early and middle crop-growing months of 1921, at Ludington, Mich., and in a number of counties of the vicinity, along the eastern shore of Lake Michigan. Conditions were similar in many other sections of the United States, but as viewed locally, it appeared frequent rains were falling not far away. This was due partly to mere chance, several storm paths having been just to the north or south, but none for a number of weeks over the strip covering Ludington. However, in some degree, it seemed local causes were operating. Several good rains occurred just across the Lake to the west. Frequently clouds appeared in the west as if to produce rain, but were dissipated without doing so. Frequently local thunderstorms appeared to form just east of the station, and thunder was heard and showers were reported. On four successive days in one case, heavy clouds were observed in the middle of the day in the east, while overhead, and in the west, north, and south the sky was cloudless.

The writer has been stationed along this shore of Lake Michigan about 11 years, approximately half of the time